Topic A8: IAQ & perceived air quality

BUILDING ENERGY-EFFICIENCY INTERVENTIONS IN NORTH-EAST EUROPE: EFFECTS ON INDOOR ENVIRONMENTAL QUALITY AND PUBLIC HEALTH

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SUMMARY

INSULAtE project aims to develop a common protocol for assessment of improving energy efficiency (EE) of dwellings on indoor environmental quality (IEQ) and public health in Europe. So far, measurement data on IEQ parameters (PM, CO, CO_2, VOCs, formaldehyde, NO_2, radon, T and RH) and questionnaire data from occupants were collected from 16 multifamily buildings (94 apartments) in Finland and 20 (96 apartments) in Lithuania before renovation. Most parameters were within recommended limits; however, the data revealed different baselines (before renovation) for each country both in terms of the IEQ parameters and the respondents' satisfaction regarding their residence and indoor air quality. Post renovation data (from one building in each country) showed potential changes in the measured parameters, while further analyses are needed once the data have been collected. The results of this project will be used in developing guidance and support the implementation of the related policies.

INTRODUCTION

National policies and programs are developed in order to fulfill the Energy Performance of Buildings Directive (EPBD) aiming to minimum energy performance for new and renovated buildings. INSULAtE project (www.insulateproject.eu) focuses on assessment of such policies and programs, aiming to develop a comprehensive protocol for assessment of the impacts of EE on IEQ and health. Two north-east European countries are involved at this point (Finland and Lithuania). Some background information has been presented by Martuzevicius et al. (2013) and Leivo et al. (2011).

METHODOLOGIES

The assessment protocol was based on the following factors: measured IEQ parameters, including 24-hour monitoring of particulate matter ($PM_{2.5}$ and PM_{10}), CO and CO_2, 1-week passive sampling of VOCs (Benzene, toluene, ethylbenzene and xylenes, BTEX), formaldehyde, and NO_2, 2-month monitoring of T and RH, 1 or 2 month passive sampling of radon; as well as occupant behaviour, thermal comfort, and self-reported health and wellbeing by questionnaires and activity logs. In addition, QA/QC practices included standard operating

procedures, coding system and logging journals. The assessment will be performed before and after renovation (pre and post energy improvement intervention). During the period of 2011-2013, 94 apartments in 16 multifamily buildings in Finland and 96 apartments in 20 multifamily buildings in Lithuania were monitored before renovation, and out of them, 6-7apartments per building for each country post renovation.

RESULTS AND DISCUSSION

Information of building characteristics and types of renovation was collected from most of the buildings (to be updated). The age of recruited buildings were 42±15 years in Finland (N=15) and 42±17 years in Lithuania (N=17). Most of the buildings (13/15) in Finland had mechanical ventilation, while all buildings (N=20) in Lithuania had natural ventilation. In the first phase of the project, different types of renovation were planned, including adding thermal insulation, installation of energy efficient windows, updating heating and/or ventilation system, as well as installation of heat recovery system into ventilator.

The concentrations of measured parameters before renovation were presented in Table 1. Indoor and outdoor $PM_{2.5}$ levels were 8.97±17.90 μg m^{-3} and 8.57±8.55 μg m^{-3} in Finland and 11.59±13.15 μg m^{-3} and 20.20±14.58 μg m^{-3} in Lithuania. Indoor CO_2 levels averaged 701±182 ppm in Finland and 1027±386 ppm in Lithuania; with 5% and 47% apartments exceeding 1000 ppm, respectively. Average NO_2 concentration was 6.60±3.65 μg m^{-3} in Finland and 14.03±7.89 μg m^{-3} in Lithuania. Formaldehyde averaged 17.47±6.92 μg m^{-3} in Finland and 23.16±10.47 μg m^{-3} in Lithuania. Volatile organic compounds (VOCs), showing only benzene, toluene, ethylbenzene and xylenes (BTEX) levels in this paper, averaged 9.27±14.02 μg m^{-3} in Finland and 22.77±25.21 μg m^{-3} in Lithuania. Fifteen apartments in Finland had low radon concentrations (< 20 Bq m^{-3}). Rest of the apartments averaged 71.52±60.11 Bq m^{-3} (N=79) and five apartments exceeded 200 Bq m^{-3}.The levels in 42 apartments in Lithuania averaged 26.55±16.36 Bq m^{-3}. Carbon monoxide was detected in two apartments in Finland with negligible levels (<1 ppm) and in 28 apartments in Lithuania (levels averaged 0.50±0.71 ppm, data not shown).

Table 1. Measured IEQ parameters in Finland and Lithuania before renovation.

Parameter	Unit	Finland					Lithuania				
		N	Average	SD	Median	95th	N	Average	SD	Median	95th
Indoor $PM_{2.5}$	μg m^{-3}	92	8.97	17.90	4.85	33.15	93	11.59	13.15	8.51	26.73
Outdoor $PM_{2.5}$	μg m^{-3}	90	8.57	8.55	6.28	26.58	85	20.20	14.58	17.37	48.52
Indoor PM_{10}	μg m^{-3}	92	22.46	32.91	14.04	61.06	93	21.90	18.77	18.44	54.75
Outdoor PM_{10}	μg m^{-3}	90	19.97	19.61	13.34	59.76	85	32.41	29.95	26.10	81.47
CO_2	ppm	92	701	182	669	1000	88	1027	386	968	1807
NO_2	μg m^{-3}	82	6.60	3.65	5.63	13.92	88	14.03	7.89	13.07	29.95
Formaldehyde	μg m^{-3}	82	17.47	6.92	16.58	29.85	95	23.16	10.47	21.15	44.17
BTEX[a]	μg m^{-3}	72	9.27	14.02	5.68	31.06	95	22.77	25.21	13.53	80.44
Radon[b]	Bq m^{-3}	79	71.52	60.11	50.00	260.00	42	26.55	16.36	25.38	68.93

[a] BTEX compounds (selected VOCs) refer to the chemicals benzene, toluene, ethylbenzene and xylenes;

[b] 2-month sampling in Finland (alpha track method) and 1-month sampling in Lithuania (gamma dose rate measurements).

Housing quality and health information were collected with a sample of 190 adults (one per apartment). A total of 83 people answered the questionnaire in Finland and 56 people in Lithuania. The respondents were relatively older (average age 59 in Finland and 54 in Lithuania), and a larger percentage was female (61% in Finland and 64% in Lithuania), as compared to general population. Some 93% of the respondents in Finland and 69% in Lithuania reported being satisfied or fairly satisfied with their residence; whereas about 76% and 59% were satisfied or fairly satisfied with indoor air quality, respectively. Responses to thermal condition (indoor heating temperature) were more or less corresponding to the measurements: low temperature (≤20ºC) was reported in 82% apartments and measured in 61% apartments in Lithuania; high temperature (≥22ºC) was reported in 28% apartments and measured in 77% apartments in Finland.

In each country, post renovation measurements were finished in one building (seven apartments in Finland and six in Lithuania) at this point. The impacts of renovation on IEQ parameters varied widely in each apartment, no solid conclusion could be established based on the limited samples. For future reference, thermal index (TI) values were calculated according to the Finnish Housing Health Guide, based on the following formula (1):

$$TI = (T_s - T_o)/(T_i - T_o) \times 100 \quad (1)$$

where T_s is surface temperature, ºC; T_o is outdoor temperature, ºC; and T_i is indoor temperature, ºC. Based on the Guide, TI ≥87 is considered a good level. In both countries, TI increased about 3% (91±5 vs. 94±3) post renovation. The good level of TI was observed in all apartments (N=11) post renovation while it was observed in eight apartments pre renovation.

CONCLUSIONS

Most measured parameters before renovation were within recommended limits. However, these baseline levels were different in each country. The effects of renovation on IEQ and occupant health will be further analyzed with updating data to support the development of the assessment protocol.

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REFERENCES

Martuzevicius D, Prasauskas T, Turunen M, et al. (2013) Improving Energy Efficiency of Housing Stock: Demonstration of Impacts on Indoor Environmental Quality and Public Health in Northern Europe. In: Proceedings in Environmental Health in Low Energy Buildings conference, Vancouver, Canada.

Leivo V, Turunen M, Prasauskas T, et al. (2011) Assessment of Improving Energy Efficiency of Buildings: Impacts on Indoor Environmental Quality and Public Health in Europe. In: Proceedings of World Sustainable Building Conference, Helsinki, Finland.

Ministry of social affairs and health, “Finnish Housing Health Guide” (Sosiaali- ja terveysministeriö, “Asumisterveysohje”, Oppaita 2003:1). ISBN 952-00-1301-6, ISSN 1236-116X. Helsinki 2003 (In Finnish).